Reversing the concept of impact and push-off in gait?

Gibbs, Sheila; Wang, Weijie; Arnold, Graham; Meadows, Barry

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Sheila Gibbs SRP MSc CSci PhD student 2014

Supervisors Weijie Wang, Barry Meadows, Graham Arnold

INTRODUCTION

In normal gait, the vertical component of the ground reaction force (FZ) forms a double hump shape with both humps approximately equal in size and their magnitude is greater than bodyweight (BW) as shown in Figure 1.

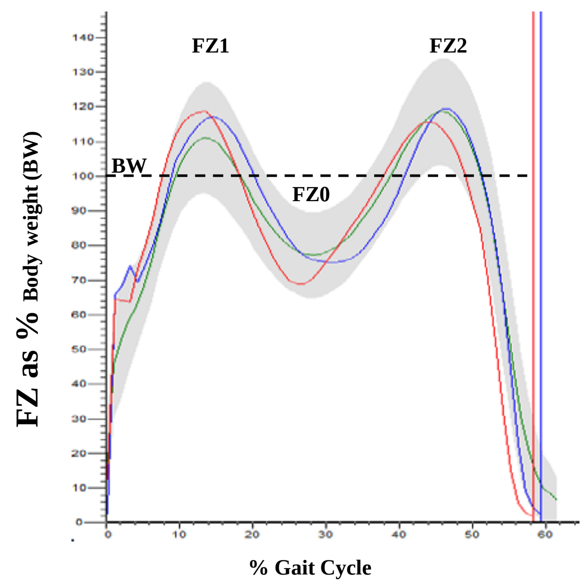

Figure 1: Normal vertical force peaks in gait defined as FZ1 and FZ2

In biomechanical texts and in clinical practice it is generally accepted that the first hump (FZ1) is associated with arrest of the downward motion of the centre of mass (CoM) as the foot impacts the ground[1, 2], and the second hump (FZ2) is the action of 'push-off' as the body is propelled upwards and forwards as shown in Figure 2.

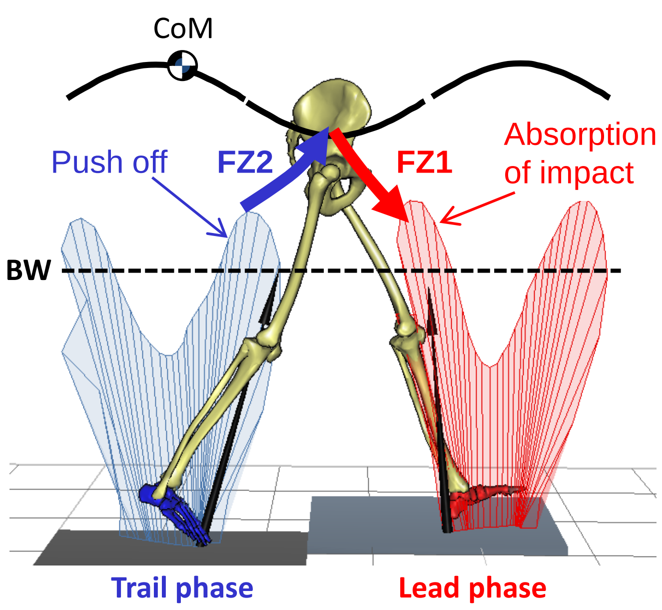

Figure 2: The currently held beliefs of the roles of FZ1 and FZ2 in normal gait

FZ2 is often reduced below body weight in cerebral palsy (CP) but is generally ignored as it is perceived to be a poor push off. This aspect of gait remains unclear or the implications of inadequate vertical force generation in the second half of stance. This current study investigated the biomechanical relationships between the forces and CoM in normal and CP gait.

AIMS AND OBJECTIVES

The principle aim of this study was to clarify the biomechanical relationship between the vertical forces generated by the legs and the vertical support of the CoM during walking. The objectives were to: ascertain the scope of the problem in children with diplegic CP; define a gait cycle based on CoM motion; and calculate the impulses generated from each leg during the single and double support phases of gait.

METHODS AND MATERIALS

Three-dimensional motion and force data was acquired using an eight camera Vicon® motion capture system and two Kistler® force platforms. The study included 53 normal adults (154 trials), 33 normal children (89 trials) and 58 children (154 trials) with diplegic CP. All walked in the lab at their own speed across two unmarked platforms embedded in the floor. A minimum of three walks with good force platform data were acquired. Force data was normalised to body weight to allow comparison between subjects. The areas under the force graphs (Impulse) were compared during the single and double support phases of gait to determine the contribution of each leg to the vertical support of the CoM.

RESULTS

The results showed that in CP the magnitude of FZ2 was significantly lower than in adults and children as shown in Table 1. This was the case for almost 40% of the CP children.

Table 1: Magnitude of FZ2 in the 3 groups. Ad = adult, Pa = paed, CP = cerebral palsy

Magnitude of FZ2		N	Mean	SD	Ad Pa	Ad CP	Pa CP
	Ad	154	116.98	8.30			
FZ2	Pa	89	115.57	9.08	0.32	0.00	0.00
	CP	138	103.31	22.7			

Examining the impulse contributions during SS and DS that in all groups the trailing leg contributed significantly more than the leading leg (Table 2). It also revealed that in CP the trailing leg failed to generate adequate impulse during SS.

Table 2: Percentage impulse contributions from each leg during single and double support. Ad = adult, Pa = paed, CP = cerebral palsy

% Impulse		N	Mean	SD	Ad Pa	Ad CP	Pa CP
Trail	Ad	154	86.05	14.25			
single	Pa	139	66.96	18.97	0.00	0.00	0.00
support	CP	89	59.68	24.49			
Trail	Ad	154	9.55	9.69			
double	Pa	139	20.28	10.96	0.00	0.00	0.02
support	CP	89	24.03	13.87			
Lead	Ad	154	4.40	5.00			
double	Pa	139	12.77	10.46	0.00	0.00	0.01
support	CP	89	16.29	14.47			

When the descent velocity of the CoM was examined (Table 3) it was clear that in CP the trailing leg was failing to control the velocity i.e. the leg was failing to generate adequate force.

Table 3: Percentage reduction in descent velocity of the CoM

Velocity		N	Mean	SD	Ad Pa	Ad CP	Pa CP
	Ad	154	86.13	16.61			
% drop	Pa	139	61.27	24.38	0.00	0.00	0.02
	CP	89	54.00	28.75			

DISCUSSION

Integration of the force and motion of the CoM showed that FZ2 was associated with controlling downward motion of the CoM. This is contrary to the belief that control of CoM descent velocity is carried out by the leading phase. In contrast, FZ1, currently believed to be associated with impact, is actually associated with upwards acceleration of the CoM. This reverses the traditionally accepted concepts of impact and push off.

In almost 40% of the children with CP, there was a reduced ability to generate an adequate vertical force which, resulted in a reduced ability to control the descent velocity of the CoM. The mean reduction in descent velocity during SS in CP was only 54% compared to 86% in adults.

CONCLUSIONS

This study has three principal findings:

1. FZ2 is associated with controlling the descent velocity of the CoM i.e. impact control
2. FZ1 is associated with the upwards acceleration of the CoM – it is NOT impact
3. In CP, 40% were failing to generate an FZ2 of at least body weight

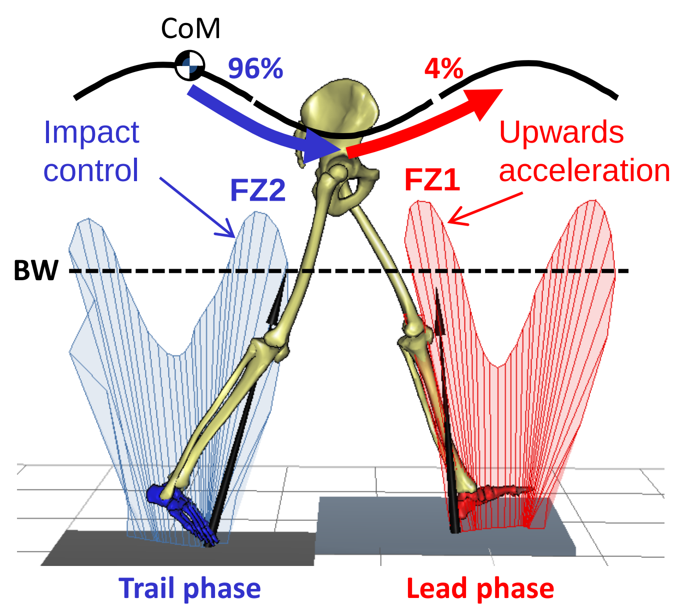

Figure 3: The roles of FZ1 and FZ2 in normal gait

This study shows that the roles of FZ1 and FZ2 need to be reconsidered. It highlights the importance of the role of the trailing phase in gait and failure to generate an adequate FZ2 should be given priority in patient management.

This new knowledge has significant implications from a clinical perspective, not only in CP, but in other pathologies such as amputees and spina-bifida. It has significant implications for the design and manufacture of orthotics in CP and potentially for the design of prosthetic feet that reportedly absorb the forces at impact to give back for push off phase of gait. This study only considered in detail, the vertical forces in relation to the vertical motion of the CoM.

REFERENCES

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